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Network Externalities, Transport Costs and Tariffs

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ABSTRACT *This paper formulates a reciprocal market model of international duopoly with network externalities to reconsider welfare effects of reductions in transport costs and tariffs. Depending on the magnitude of network externalities, we show two possibilities. One of them, which emerges under strong network externalities, illustrates that freer trade unambiguously improves welfare for any initial level of trade barriers. This finding provides an affirmative evaluation of freer trade.*

KEY WORDS: network externality, duopoly, transport costs, tariffs

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1 Introduction

One of the outstanding trends of the modern economy is a rapid growth of network industries, e.g., the internet and communications services. This fact generates a large literature on network externalities mainly in industrial organization.[1] Among others, Katz and Shapiro (1985) are possibly the first to incorporate network externalities into an oligopoly model. Using a similar model, Economides (1996) shows that incumbent firms can benefit from an increase in the number of firms in the industry.

Based on these developments in industrial organization, there has been a literature identifying implications of network externalities for international trade.[2] Extending Economides' (1996) model to a two-country world, Kikuchi and Kobayashi (2007) show the profitability of the opening of trade in the presence of network externalities. Yano and Dei (2006) find an intriguing role of network externalities, demonstrating that discrete demand shift leads a monopolistic firm to charge price below marginal cost under network externalities. Furthermore, allowing for a foreign competitor in a Katz-Shapiro (1985) model, Ji and Daitoh (2008) consider how network externalities affect the optimal subsidy for an interconnection investment. While these studies clarify important aspects of network externalities in international trade, none of them addresses welfare effects of trade liberalization. Extending Farrel and Saloner's (1992) model, Klimenko (2009a, b) examines compatibility policies in an open economy.[3]

This paper reconsiders welfare effects of reductions in transport costs and import tariffs under network externalities by combining the Katz-Shapiro (1985) model with a reciprocal market model.[4] Within this framework, we find that the presence of network externalities has a considerable influence on welfare effects of reductions in transport costs and tariffs. Concretely, we show two possibilities. The first, which arises under mild network effects, establishes a non-monotonic relationship between welfare and trade barriers. This is nothing new since the existing literature has already obtained it. In contrast, in the second case with strong network effects, reductions in trade barriers monotonically and unambiguously improve welfare. This is because less costly trade expands the network size, which favorably affects not only consumers but also oligopolistic firms. This affirmative evaluation of freer trade holds for any degree of compatibility between the two countries' network.

This paper is organized as follows. Section 2 presents a model. Sections 3 and 4 deal with the case of transport costs and tariffs, respectively. Section 5 concludes our discussion.

2 A Model

The model we develop is a straightforward combination of Katz and Shapiro (1985) and Brander and Krugman (1983). Consider two symmetric countries (Home and Foreign), two goods (Goods 1 and 2) and one factor (labor). All the Foreign variables are asterisked to distinguish them from the Home variables. Good 2 (numeraire) is produced with a unitary input coefficient so that the wage rate is internationally unity. The markets of Good 1 are segmented and duopolized by a Home firm (firm X) and a Foreign firm (firm Y). Each firm has an identically constant marginal cost $c \geq 0$ and exporting is costly due to a specific trade barrier τ, which is either a transport cost or an import tariff.[5]

Consumption of Good 1 exhibits a network externality and we employ Katz and Shapiro's (1985) formulation. In Home, there is a mass of consumers uniformly distributed in a closed interval $[0, a]$ each of whom chooses to buy either one unit of Good 1 or none. When consumer $r \in [0, a]$ purchases Good 1 from the Home firm (resp. Foreign firm), she derives utility of $r + bZ - p$ (resp. $r + bZ^* - p^*$), where r is consumer r's intrinsic utility and Z (resp. Z^*) is a network size associated with the Home (resp. Foreign) good. The parameter $b \geq 0$ measures the degree of network externalities. Hence, if both firms are active, we have $r + bZ - p = r + bZ - p^*$. Defining $p - bZ = p^* - bZ = \widetilde{p}$, consumer r is willing to buy Good 1 if and only if $r - \widetilde{p} \geq 0$ since purchasing nothing yields zero utility. Thus, any consumer $r \geq \widetilde{p}$ purchases Good 1 and the resulting aggregate demand in Home becomes $\int_{\widetilde{p}}^{a} 1dr = a - \widetilde{p}$. Denoting the Home (resp. Foreign) firm's supply into the Home market by x (resp. y), the market-clearing condition in Home is $a - \widetilde{p} = x + y$, which is inverted to get an inverse demand function: $p = a + bZ - x - y$. Foreign's counterpart is similarly obtained as $p^* = a + bZ^* - x^* - y^*$. Given these assumptions, consumer surplus in Home is computed as

$$\int_{\widetilde{p}}^{a} (r - \widetilde{p})\, dr = \frac{a^2}{2} - a\widetilde{p} + \frac{\widetilde{p}^2}{2} = \frac{a^2}{2} - a(a - x - y) + \frac{(a - x - y)^2}{2} = \frac{(x + y)^2}{2}, \quad (1)$$

where the second equality comes from the market-clearing condition. Similarly, Foreign's consumer surplus is $(x^* + y^*)^2/2$.

From the underlying assumptions, the profits of firms X and Y, π and π^*, are defined by

$$\begin{aligned} \pi &= (a + bZ - c - x - y)x + (a + bZ^* - c - \tau - x^* - y^*)x^* \\ \pi^* &= (a + bZ - c - \tau - x - y)y + (a + bZ^* - c - x^* - y^*)y^* \end{aligned}$$

The model comprises two stages. In the first stage, consumers form an expectation over Z and Z^*. Given the predetermined expectations of Z and Z^*, firms X and Y choose outputs in a Cournot-Nash fashion in the second stage. To solve this model, let us first consider the last stage. In choosing outputs, firms take Z and Z^* as given so that the first-order conditions are obtained as[6]

$$\begin{aligned} \frac{\partial \pi}{\partial x} &= a + bZ - c - 2x - y = 0 \\ \frac{\partial \pi}{\partial x^*} &= a + bZ^* - c - \tau - 2x^* - y^* = 0 \\ \frac{\partial \pi^*}{\partial y} &= a + bZ - c - \tau - x - 2y = 0 \\ \frac{\partial \pi^*}{\partial y^*} &= a + bZ^* - c - x^* - 2y^* = 0. \end{aligned}$$

In the first stage, consumers form an expectation over Z and Z^*. We assume that the Home and Foreign products are partially compatible such that $Z = x + x^* + \theta(y + y^*)$ and $Z^* = \theta(x + x^*) + y + y^*$, where $\theta \in [0, 1]$ measures the compatibility of products. By definition, $\theta = 0$ (resp. $\theta = 1$) corresponds to full incompatibility (resp. compatibility). Substituting these definitions into the above system of equations and solving for outputs, the equilibrium outputs are

$$x = y^* = \frac{a - c + (1 - b - b\theta)\tau}{3 - 2b - 2b\theta} \quad (2)$$

$$x^* = y = \frac{a - c - (2 - b - b\theta)\tau}{3 - 2b - 2b\theta}. \quad (3)$$

At this stage, we make an assumption to guarantee the stability of the Nash equilibrium:

Assumption. $3 - 2b - 2b\theta > 0$ or equivalently $b + b\theta < \frac{3}{2}$.

From (2) and (3), together with the assumption of symmetry between countries, we can exclusively focus on Home without loss of generality. It is easy to show that the maximized profit of firm X equals $x^2 + x^{*2}$. The next sections make use of these preliminaries to evaluate welfare effects of reductions in transport costs/tariffs.

3 Transport Costs and Welfare

This section presumes that τ is a transport cost, from which the Home welfare W consists of consumer surplus and firm X's profits:

$$\begin{aligned} W(\tau) &= \frac{(x+y)^2}{2} + x^2 + x^{*2} \\ &= \frac{1}{2}\left[\frac{2(a-c)-\tau}{3-2b-2b\theta}\right]^2 + \left[\frac{a-c+(1-b-b\theta)\tau}{3-2b-2b\theta}\right]^2 + \left[\frac{a-c-(2-b-b\theta)\tau}{3-2b-2b\theta}\right]^2 \\ &= \frac{\left[4(b+b\theta)^2 - 12(b+b\theta)+11\right]\tau^2 - 8(a-c)\tau + 8(a-c)^2}{2(3-2b-2b\theta)^2}. \end{aligned} \tag{4}$$

The rest of our task is to carefully examine the properties of $W(\cdot)$. Note first that the coefficient to τ^2 in (4) is positive. Taking this into account, differentiating (4) with respect to τ yields

$$W'(\tau) = \frac{\left[4(b+b\theta)^2 - 12(b+b\theta)+11\right]\tau - 4(a-c)}{(3-2b-2b\theta)^2} \tag{5}$$

$$W''(\tau) = \frac{4(b+b\theta)^2 - 12(b+b\theta)+11}{(3-2b-2b\theta)^2} > 0.$$

Since the second derivative is positive, $W(\cdot)$ is strictly convex, but we have two possibilities on the dependence of $W(\cdot)$ on τ. To make clear this, evaluating (5) at $\tau = 0$ and $\tau = \overline{\tau}$, where $\overline{\tau}$ denotes the prohibitive transport cost which is computed by setting (3) to zero: $\overline{\tau} = (a-c)/(2-b-b\theta)$. Substituting $\tau = 0$ and $\tau = \overline{\tau}$, we have

$$\begin{aligned} W'(0) &= \frac{-4(a-c)}{(3-2b-2b\theta)^2} < 0 \\ W'(\overline{\tau}) &= \frac{(1-2b-2b\theta)(a-c)}{(3-2b-2b\theta)(2-b-b\theta)}. \end{aligned}$$

Therefore, $W(\cdot)$ is negatively-sloped at $\tau = 0$ while the slope of $W(\cdot)$ at $\overline{\tau}$ can be both positive and negative. The above expression allows us to know that $W'(\overline{\tau}) > 0$ if and only if $b + b\theta < 1/2$.

The next task is to check welfare levels under free trade ($\tau = 0$) and autarky ($\tau = \overline{\tau}$). Substituting $\tau = 0$ and $\tau = \overline{\tau}$ into (4), they are respectively obtained as

$$\begin{aligned} W(0) &= \frac{8(a-c)^2}{2(3-2b-2b\theta)^2} \\ W(\overline{\tau}) &= \frac{3(a-c)^2}{2(2-b-b\theta)^2}. \end{aligned}$$

Taking the ratio between these two yields

$$\frac{W(0)}{W(\overline{\tau})} = \frac{8(2-b-b\theta)^2}{3(3-2b-2b\theta)^2}.$$

Subtracting the denominator from the numerator yields $-4(b+b\theta)^2+4(b+b\theta)+5$, which is positive under Assumption made above. Therefore, free trade necessarily leaves both countries better off than autarky.

Summarizing the results obtained above, the welfare effects of transport cost reductions are formally stated as follows.

Proposition 1.
If $b+b\theta$ is small enough to have $b+b\theta < 1/2$, $W(\tau)$ takes a U-shape and hence transport cost reductions may harm welfare (Figure 1). In contrast, if $b + b\theta$ is large enough to have $3/2 > b + b\theta > 1/2$, $W(\tau)$ is monotonically decreasing for any $\tau \in [0, \overline{\tau}]$, namely, a reduction in transport costs necessarily entails welfare gains (Figure 2).[7]

The intuitions behind this result are as follows. For this purpose, we note that welfare effects of transport cost reductions are decomposed as follows. First, trade promotes competition between the firms and contributes to increasing consumer surplus. Second, reductions in trade barriers make foreign entry easier and hence a part of the domestic firm's profit is shifted abroad. This has a negative welfare effect. Third, a reduction in transport costs inevitably induces more wastes of resources in the case of transport costs, which is welfare-reducing. Fourth, the procompetitive effect serves to expand the network size in both countries, which can benefit both the consumers and the oligopolistic firms.

If the network externality parameter $b + b\theta$ is small enough, the well-known result of U-shaped welfare is reestablished. If the initial level of transport cost is too high, the profit-shifting effect and an increase in wasteful resources dominate the other favorable effects. As a result, transport cost reductions can be harmful. When either reductions in transport costs are substantial or the initial transport cost is too small, freer trade benefits welfare since the positive effects outweigh the negative effects.

In contrast, the above ambiguity vanishes if the network externalities are sufficiently strong. This is because the positive effect triggered by network expansion plays a dominant role in the total welfare effect. Therefore, $W(\tau)$ becomes monotonically decreasing in τ, from which we can conclude that freer trade definitely improves welfare for regardless of initial levels of transport costs.

4 Tariffs and Welfare

While the previous section regards τ as a transport cost, this section turns to another case where τ is an import tariff. Despite this difference in interpretations, the task is substantially the same as that in the transport cost case. We begin by defining welfare of Home in the present case. All we have to do is to add tariff revenue τy to $W(\cdot)$ in (4). Then, welfare in the tariff case is

$$\begin{aligned} \widetilde{W}(\tau) &= W(\tau) + \tau y \\ &= \frac{[4(b+b\theta)^2 - 12(b+b\theta) + 11]\,\tau^2 - 8(a-c)\tau + 8(a-c)^2}{2(3-2b-2b\theta)^2} + \frac{\tau[a-c-(2-b-b\theta)\tau]}{3-2b-2b\theta} \\ &= \frac{-(1-2b-2b\theta)\tau^2 - 2(1+2b+2b\theta)(a-c)\tau + 8(a-c)^2}{2(3-2b-2b\theta)^2}, \end{aligned} \tag{6}$$

where a tilde indicates a tariff case.

As in the case of transport costs, let us differentiate $\widetilde{W}(\cdot)$ to get

$$\widetilde{W}'(\tau) = \frac{-(1-2b-2b\theta)\tau - (1+2b+2b\theta)(a-c)}{(3-2b-2b\theta)^2} \tag{7}$$

$$\widetilde{W}''(\tau) = \frac{-(1-2b-2b\theta)}{(3-2b-2b\theta)^2}. \tag{8}$$

Unlike the transport cost case, the sign of both $\widetilde{W}'(\cdot)$ and $\widetilde{W}''(\cdot)$ can be both positive and negative depending on the parameters. From (8), we see that $\widetilde{W}(\cdot)$ is strictly concave if and only if $b + b\theta < 1/2$.

In order to know the slope at two values $\tau = 0$ and $\tau = \overline{\tau} = (a-c)/(2-b-b\theta)$, substituting these into (7) yields

$$\begin{aligned} \widetilde{W}'(0) &= \frac{-(1+2b+2b\theta)(a-c)}{(3-2b-2b\theta)^2} < 0 \\ \widetilde{W}'(\overline{\tau}) &= \frac{-(1+b+b\theta)(a-c)}{(3-2b-2b\theta)(2-b-b\theta)} < 0. \end{aligned}$$

Accordingly, $\widetilde{W}(\cdot)$ is monotonically negatively-sloped for any positive tariff.

The welfare comparison between free trade and autarky in the last section can straightforwardly apply to the tariff case because we easily find $W(0) = \widetilde{W}(0)$ and $W(\overline{\tau}) = \widetilde{W}(\overline{\tau})$. Considering these results, the welfare effects of tariff reductions are formally stated in:

Proposition 2.
If $b + b\theta$ is small enough to have $b + b\theta < 1/2$, $W(\tau)$ takes a strictly concave and inverted U-shape (Figure 3). In contrast, if $b + b\theta$ is large enough to have $3/2 > b + b\theta > 1/2$, $W(\tau)$ is strictly convex in τ (Figure 4). While reductions in tariffs ensure welfare gains, there exists an import subsidy $\tilde{\tau} \equiv -(1+2b+2b\theta)(a-c)/(1-2b-2b\theta)$ which maximizes joint welfare of both countries in the former subcase.[8]

Proof. Obvious from the above arguments. From $\widetilde{W}'(\tau) = 0$ in (7), we obtain $\tilde{\tau} = -(1+2b+2b\theta)(a-c)/(1-2b-2b\theta) < 0$.

Let us interpret this result intuitively. What makes the tariff case differ from the transport cost case is that the absence of waste of resources. This is because tariff revenue compensates the losses associated with wasteful trade. Thus, the result is more straightforward than the transport cost case. In the tariff case, trade liberalization monotonically improves welfare regardless of the initial tariff and the network size parameter.

However, it is worth mentioning the subtle difference between the two subcases illustrated in Figures 3 and 4. If the network externality parameter is sufficiently small, there exists an import subsidy $\tilde{\tau}$ which maximizes welfare of both countries. This implies that both countries reach the highest welfare if they cooperatively choose $\widetilde{\tau}$. On the other hand, such a welfare-maximizing level of import tariff/subsidy does not exist if the network externality parameter is sufficiently large. Despite this difference, both subcases commonly predict that trade liberalization is welfare-improving, which can provide an affirmative rationale for multilateral trade liberalization.

5 Concluding Remarks

Developing a reciprocal dumping model of international trade with network externalities, we have illustrated how the presence of network externalities influences gains from reductions in transport costs and import tariffs. When the network effects are sufficiently strong, they prove to benefit welfare in an unambiguous and monotonic fashion. This is mainly because expansion in network sizes positively affects welfare and dominates the other negative effects through profit-shifting and wasteful resources. In view of the growing presence of network industries in modern world trade, our results have certain relevance on considering welfare effects of international trade. However, we admittedly recognize that our analysis has been based on a number of simplifying assumptions. It is our future research agenda to elaborate our results in a more general setting.

Notes

1. See Shy (2001) for a formal definition of network externalities. For recent developments in literature, see, for example, Farrell and Klemperer (2007).
2. While we adopt an oligopolistic model, some predecessors employ a monopolistically competitive model, e.g., Harris (1998), Kikuchi (2002, 2003) and Kikuchi and Ichikawa (2002).
3. We should comment that Krishna (1988) is the first to incorporate network externalities into the models of oligopolistic trade. She makes clear how network externalities affect the effects of unilateral adoption of trade policies.
4. See, among others, Brander (1981) and Brander and Krugman (1983).
5. We allow for negativity of τ (import subsidy) in the tariff case.

6. The second-order conditions are satisfied.
7. Trade gains are ensured in the marginal case in which $b + b\theta = 1/2$ as well.
8. $\widetilde{W}(\tau)$ becomes negatively linear in the special case of $b + b\theta = 1/2$.

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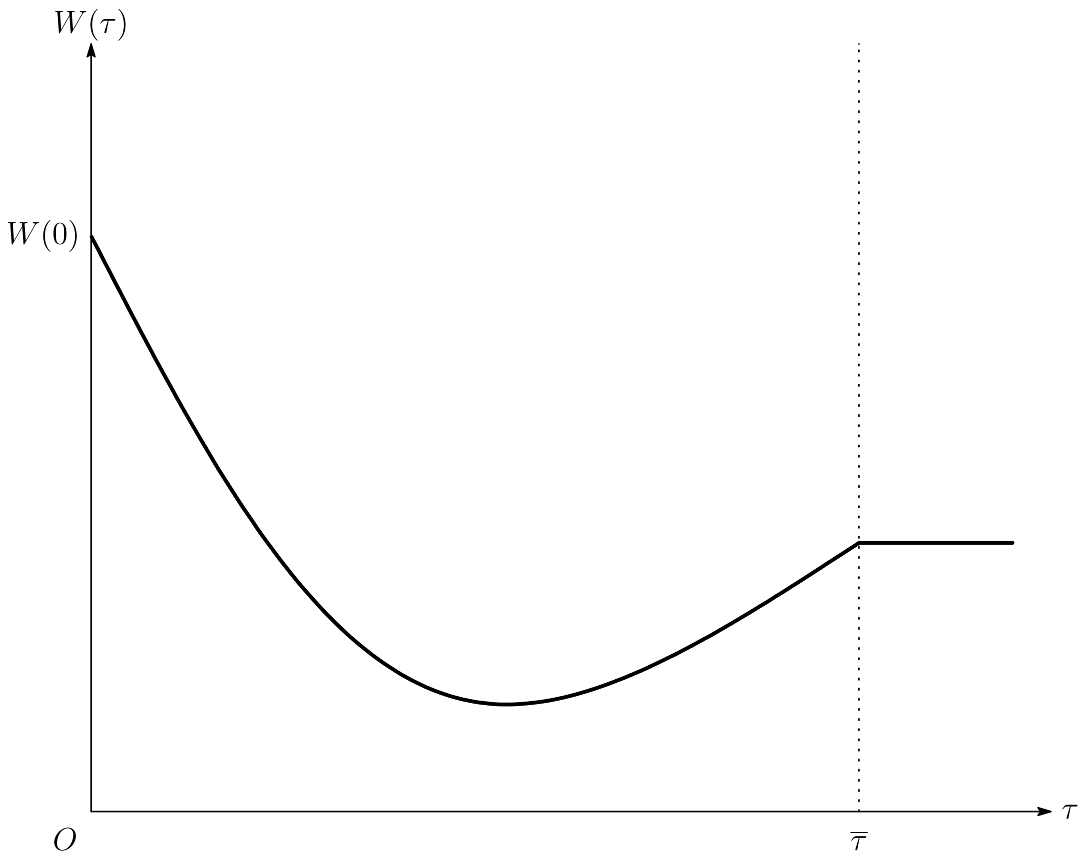

Figure 1: Transport cost case (1)

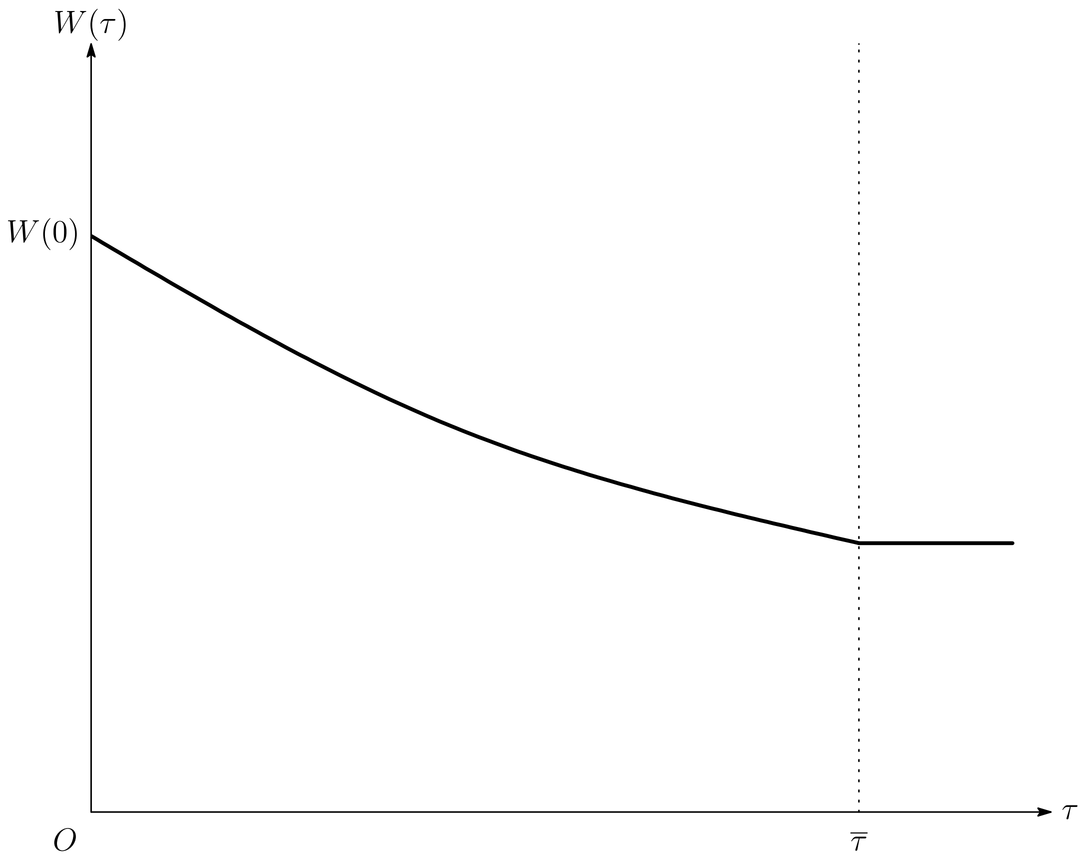

Figure 2: Transport cost case (2)

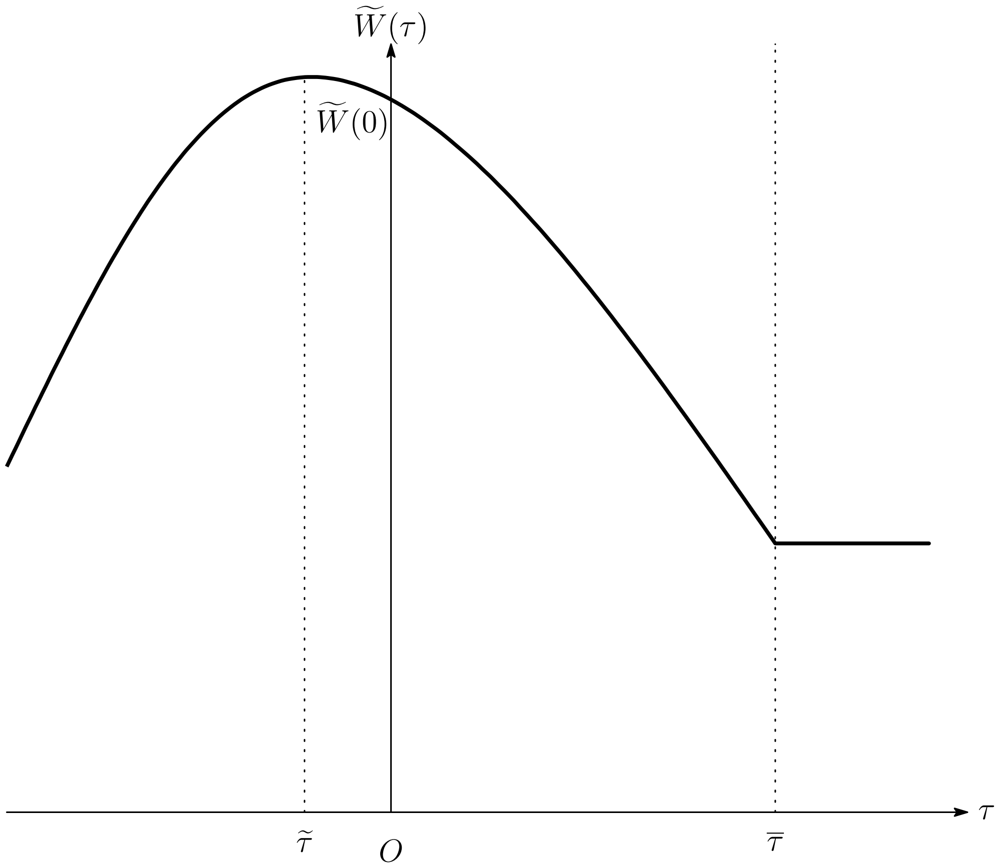

Figure 3: Tariff case (1)

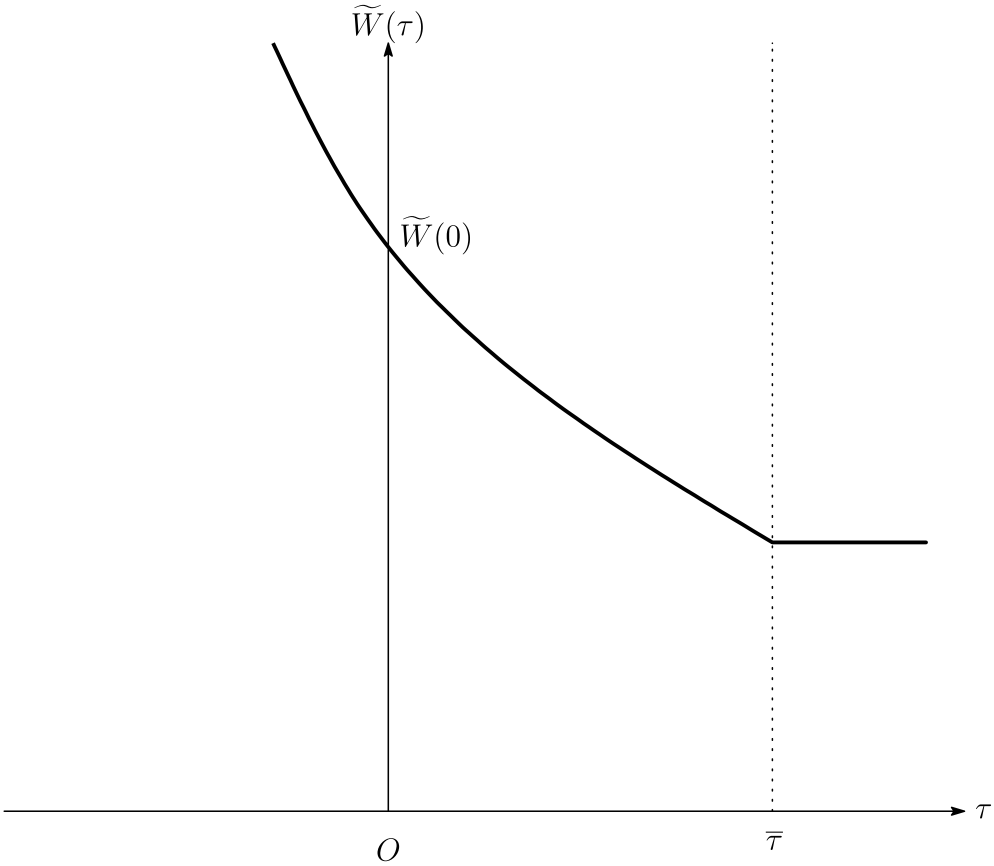

Figure 4: Tariff case (2)